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SEXUAL REINFORCEMENT IN THE FEMALE RAT

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Sexual reinforcement in the female rat was studied in a preparation that allowed continuous operant responding for access to a male rat leading to intromission. Experiment 1 used a high operant level nose-poke response to test the possible reinforcing effects of some components of access to a male. A simple tone stimulus used as a conditioned reinforcer and two odor stimuli, target male bedding and emulsified preputial gland, were tested. None of these contingent events altered responding above or below operant level. Access to the male, which was always accompanied by intromission, immediately increased response rate when it was made contingent upon the nose-poke response. Performance on fixed-ratio schedules was erratic, and response rate was low in comparison to typical food-reinforced responding. An interresponse-time analysis indicated, however, that some effect of the ratio contingency may have been present. In Experiment 2, several modifications of the procedure were tested with the objective of creating a more tractable preparation for behavior analysis. Response type and the hormone delivery method were changed, and 2 target males were used instead of 1. The latter tripled the average number of reinforcers earned in a single session. Differences between sexual and other reinforcers are discussed in terms of procedural, quantitative, and motivational aspects of the sexual reinforcement procedure.

Key words: sexual reinforcement, sexual motivation, fixed-ratio schedules, pacing, estrogen, nose poke, rat

The analysis of the control of operant behavior by positive reinforcers has been concerned very largely with the effects of food as a reinforcer. Although we now have a virtual mastery of the ways in which food reinforcers can be used to manipulate operant behavior, there remains an uncertainty as to the extent to which this body of knowledge is particular to food reinforcers. Food is an ingestive homeostatic reinforcer. The available evidence suggests the other major ingestive homeostatic reinforcer, water, has similar functional properties. Although there are reliable differences in the detailed form of food- and water-reinforced operants (Allan & Matthews, 1989; H. Jenkins & Moore, 1973; Papadouka & Matthews, 1995), water supports rapid acquisition of an operant and sustains behavior on extended schedules of reinforcement with similar, although not identical, performance patterns in response to particular schedule requirements (Hogan & Roper, 1978). Overall, water is behaviorally quite similar to food in comparison to other types of reinforcer.

Thermal reinforcement, which is a noningestive homeostatic reinforcer, may have functional properties that are distinct from the ingestive reinforcers. It has been shown to support responding on fixed-ratio (FR) schedules no larger than 25, and there has been little indication of temporal discrimination on differential-reinforcement-of-low-rate schedules (Matthews, 1968[1]). In studies with parametric manipulations sufficiently broad to allow reasonable comparisons across qualitatively different reinforcers, manipulations of food and water deprivation (drive) produce large effects that do not subside over sessions (Carlton, 1961; Clark, 1958; Ferster & Skinner, 1957; Shull & Brownstein, 1968). Manipulation of the reinforcer stimulus magnitude parameter (incentive) produces weaker effects on responding that tend to subside over sessions and are subject to contrast enhancement and depression when reinforcer magnitude is abruptly shifted (Black, 1969).

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[1] Matthews, T. J. (1968). *Schedules of intermittent thermal reinforcement in the rat.* Paper presented at the meetings of Eastern Psychological Association, Atlantic City, NJ.

Thermal reinforcement generates a far more robust drive effect (Matthews, 1971) and a far weaker incentive effect (Matthews, Pinsky, & Storax, 1974). Overall, the parametric effects of thermal reinforcement are more similar to those of electric shock escape (Fantino, 1973) than to food reinforcement.

Sexual reinforcement represents yet another type of motivational system; it is noningestive and nonhomeostatic. Unlike stimulus reinforcement (Hogan & Roper, 1978) or running-wheel activity (Iversen, 1993), which are also noningestive and probably nonhomeostatic, sexual reinforcement is very tightly tied to biological survival throughout the species of interest for behavior analysis. As Crawford, Holloway, and Domjan (1993) have summarized, there has been relatively little work on the behavioral properties of sexual reinforcement.

Various measures have been used to assess the reinforcing properties of sexual contact in animals. In the earliest studies, female rats crossed an electrified grid to gain access to the male (M. Jenkins, 1928; Nissen, 1929; Warner, 1927). Crossings were very slow and were restricted to the peak period of the estrus cycle. Running responses have been shown to increase in rate with sexual reinforcement for female rats, even if intromission is not allowed (Eliasson & Meyerson, 1975). Various preference tests have been used to identify the reinforcing properties of targets. T-maze choice tests (Kagan, 1955; Whalen, 1961) and a two-lever choice procedure (French, Fitzpatrick, & Law, 1972) have shown stable preferences in females, even between two sexually responsive male targets.

Using a bar-press response, Bermant (1961) replicated the ''pacing'' effect in which the latency of the female's postcopulatory return to the male increased as the intensity of the previous sexual encounter increased. Simple mounting was followed by short latencies to return to the male, whereas intromission and ejaculation were followed by longer latencies (Pierce & Nutall, 1961; see Erskine, 1989, for a review). This effect is likely to be related to aversive aftereffects of the sexual encounter. In fact, Bermant also showed an attenuation of the return delay following an intense encounter when the female's vaginal area was treated with a topical anesthetic. Thus, tactile stimulation of the genital region is probably not an unequivocally positive component of sexual reinforcement in the female. This result stands in distinction to the more familiar incentive effect, in which the strength of responding is stronger following a more intense reinforcer. This difference could be resolved by testing subjects trained on a sufficiently intermittent reinforcement schedule to minimize postreinforcement effects on response rate.

Few experiments have applied reinforcement schedules to the analysis of sexual reinforcement, a technique that has been very helpful in the analysis of other reinforcers. Kevern (1976) used FR schedules of copulatory access to males for bar pressing by female rhesus monkeys. Although there was a clear variation in responding with the estrus cycle, the characteristic intermittent mating pattern of primates did not lend itself to experimental analysis.

The present study is an initial exploration of the functional characteristics of sexual reinforcers in a preparation that may eventually allow comparisons to reinforcers from other types of motivational systems. Rats were chosen as subjects because their characteristic sexual behavior lends itself to repeated presentations of reinforcement (Pfaff & Lewis, 1974). In a sexually active pair, the courtship phase includes mutual genital and facial sniffing followed by a hop-dart response by the female that positions her at a short distance from the male, facing away from him. The male then approaches the female from the rear, grasping her by the flanks with his forepaws. When mounted, the female flexes her back and everts her tail, exposing the vaginal orifice (lordosis). The male will then intromit and quickly withdraw. This sequence is repeated at intervals of a few seconds to a minute until the intromission is accompanied by ejaculation. The usual number of intromissions before ejaculation is between 5 and 12. It is these intromissions that were used as the reinforcer for the female's operant behavior.

In the first study we examined the effects of some elements of sexual reinforcement that may contribute to its capacity to support responding by the female. We also observed performance on FR schedules of reinforcement. In the second experiment, we used another response type, the nose press, which had a lower operant level. Also, we attempted

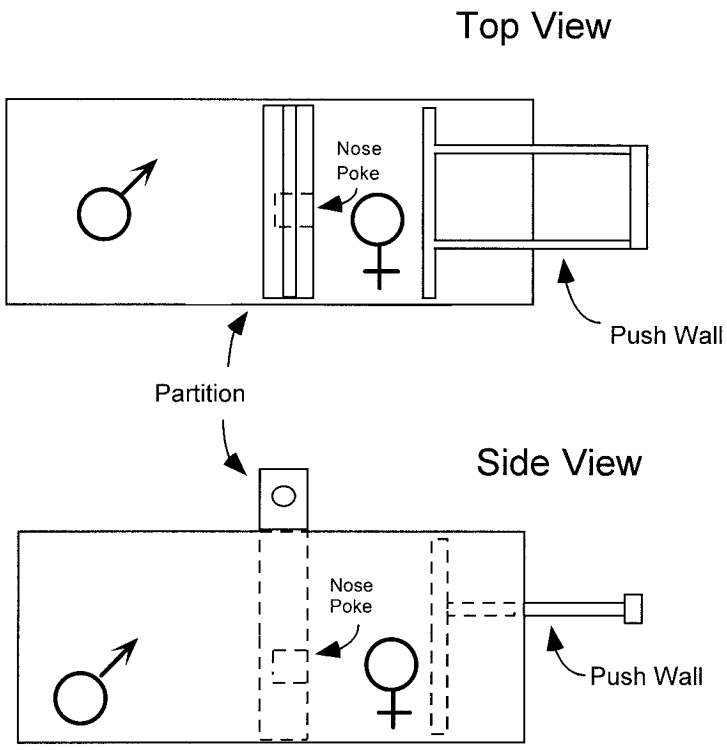

Fig. 1. In this test chamber shown from the top and side, the female is initially placed in the right compartment and the target male in the left. On a correct response by the female, the partition is lifted and the push wall moved forward to assure that the female goes into the male's compartment and that the male does not come into the female's compartment.

to extend the number of intromissions that can be presented in a test session by using 2 males as sexual targets.

EXPERIMENT 1

Method

Subjects. Six sexually naive female Long-Evans rats purchased from Charles River were used as subjects. They were bilaterally ovariectomized by the vendor and were delivered at approximately 225 g. The target rats were 6 sexually experienced male Long-Evans rats who were described as retired breeders. Subjects were housed in a reversed day/night cycle room and were tested during the dark phase of their cycle. Subjects' cages were positioned in the room's ventilation flow so that the female's exposure to male odors was minimized.

Each female's sexual motivation was maintained by injections of 1 μg of estradiol benzoate in an oil vehicle delivered on alternate days throughout the study. Injections were administered subcutaneously on the subject's back between the front shoulders.

Apparatus. The test chamber is shown in Figure 1. The male's and female's compartments were 45 cm by 30 cm by 30 cm and were separated by a vertically removable partition. The ceilings of both chambers were access doors and the floor was covered with rodent bedding. The rear wall of the female's compartment could be moved forward to the partition and served both to move the female into the male's compartment and to prevent

the male from entering the female's compartment. All surfaces were constructed of clear Plexiglas.

The operant was a nose-poke response that in pilot work had a sufficiently high spontaneous rate of occurrence that shaping was not required. The response was detected by a photodetector mounted in a cylindrical opening in the female's side of the removable partition wall. The cylinder was 2.5 cm in diameter and 2 cm deep and its lower edge was 2 cm off the chamber floor. The infrared light source and photocell were positioned on either side of the cylinder opening and were recessed 1 cm into the cylinder.

The odorant delivery system consisted of a fish tank air pump that forced room air through 0.5-cm Tygon tubing. The air was introduced into the female's chamber through a 0.5-cm aperture on the rear surface of the nose-poke cylinder. To assure that the stimulus did not linger in the chamber, a 7-cm exhaust fan was mounted on the ceiling of the female's compartment and drew air through holes in the chamber floor just along the front wall of the chamber. Thus the room air flow passed over the opening of the nose-poke cylinder, quickly evacuating the odorized air. A computer-controlled solenoid valve system directed the air into the nose-poke cylinder or out into the room so that pressure did not build between odor presentations, and the odor content of the air was stable. Odors were added to the stream by passing the air over odorants in a glass cylinder (5 cm by 1 .5 cm) before delivery into the nose-poke cylinder. The male bedding odorant consisted of approximately 5 cc of bedding taken from the target male's home cage prior to the test session. The preputial odorant consisted of an emulsion of male preputial gland that had been surgically removed from sacrificed adult male rats available from another study. The material was frozen shortly after removal and emulsification and was thawed before use in the experiment.

The tone was generated by a Sonalert® device located just behind the nose-poke cylinder within the removable partition. The tone was approximately 1000 Hz and 70 db inside the female's compartment.

The presentation of the tone, the presentation of odorants, and the detection and recording of the nose-poke operant were controlled by a computer. The raising and lowering of the partition, the movement of the rear wall of the female's compartment, and the return of the female to her compartment following an intromission were all executed by the experimenter.

Procedure. The initial stages of this experiment were designed to determine whether the effective aspect of the sexual reinforcer was the physical encounter between the subject and target rats. In all sessions, the female was placed in the female compartment and was allowed to respond for 30 min. The consequences of responding varied across sessions and were as follows: Sessions 1 through 3, a 3-s tone presented immediately after each response; Sessions 4 through 6, tone plus 3-s stream of unodorized air, also presented for 3 s immediately following the response; Sessions 7 through 9; tone plus air stream odorized with male bedding; Sessions 10 through 16, tone plus air stream odorized with scent of preputial gland; Sessions 17 through 38, tone plus preputial-scented air plus sexual reinforcement.

Sexual reinforcement. The number of trials per session was dictated by the number of intromissions the target male made before ejaculation, after which the male ceased approaching the female. Reinforcement began with the sounding of the 3-s tone and the initiation of the 3-s flow of preputial scented air. At the tone, the experimenter raised the partition and moved the rear wall of the female's compartment forward to the partition. The latency of the experimenter's response allowed time for the odorant to be sensed. The forward movement of the rear wall both assured that the female would move to the male's compartment and that the male would not enter the female's compartment. It was rarely the case that the female was pushed into the male's compartment by the rear wall motion.

The mean interval between the nose-poke response and the return of the female to her compartment was 53.5 s, and the mean minimum was 24.3 s. Following the raising of the partition, the trained female moved directly into the male's compartment. The male then variously approached, sniffed, mounted, and eventually intromitted. The intromission was reliably followed by a characteristic withdrawal of the male (Pfaff & Lewis, 1974), at which

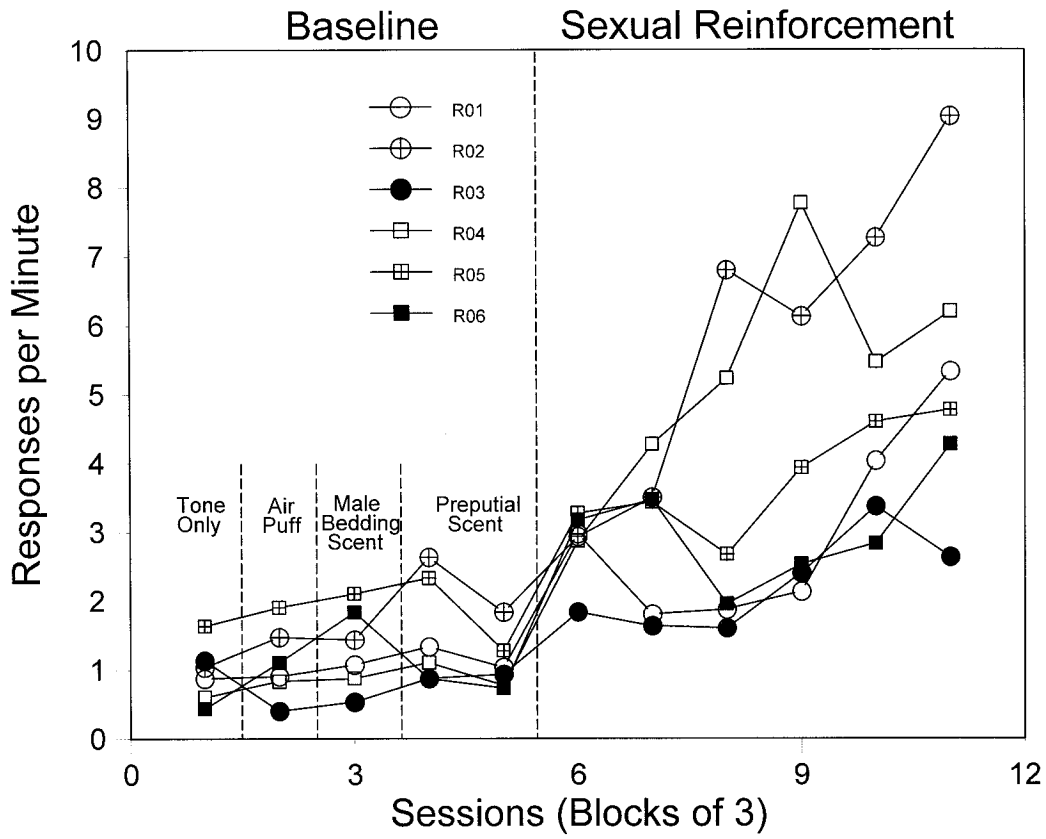

Fig. 2. Nose-poke response rates are shown for 6 subjects across five successively presented response contingencies. They were a 3-s tone, a tone plus a 3-s presentation of air at the rear of the nose-poke cylinder, tone plus air scented with bedding of a target male, tone plus air scented with an emulsion of male preputial gland, and tone plus access to a target male ending with intromission. Over Sessions 17 to 38, responses were reinforced on FR schedules proceeding from FR 1 to a value as high as FR 25. The response requirement was increased initially by one and later by three to five after two successive sessions of apparently stable responding.

time the female could be removed conveniently from the male's compartment. Upon returning the female to her compartment, the experimenter signaled the computer with a hand switch that a new trial had begun.

The 6 target males were randomly assigned to females on each session. If a male was not responsive, he was replaced by another male. In those cases, males tested early in the day were reused in sessions later in the same test day. Females were tested approximately every other day on an irregular schedule.

Fixed-ratio schedules of reinforcement for the nose-poke response. Over Sessions 17 to 38, responses were reinforced on FR schedules proceeding from FR 1 to a value as high as FR 25. The response requirement was increased initially by one and later by three to five after two successive sessions of apparently stable responding. Nonreinforced responses were followed by a 0.2-s 1000-Hz tone. The frequency and intensity of this tone were the same as those of the 3-s tone that followed a reinforced response; the tone was introduced as feedback for correct responses. No odorant was presented following nonreinforced responses.

Results

Figure 2 presents response rates for individual subjects in the five treatment conditions. As is apparent, the response rates remained low and stable through the first four treatments, indicating a failure of those treatments to effectively reinforce or suppress responding. The high spontaneous rate of

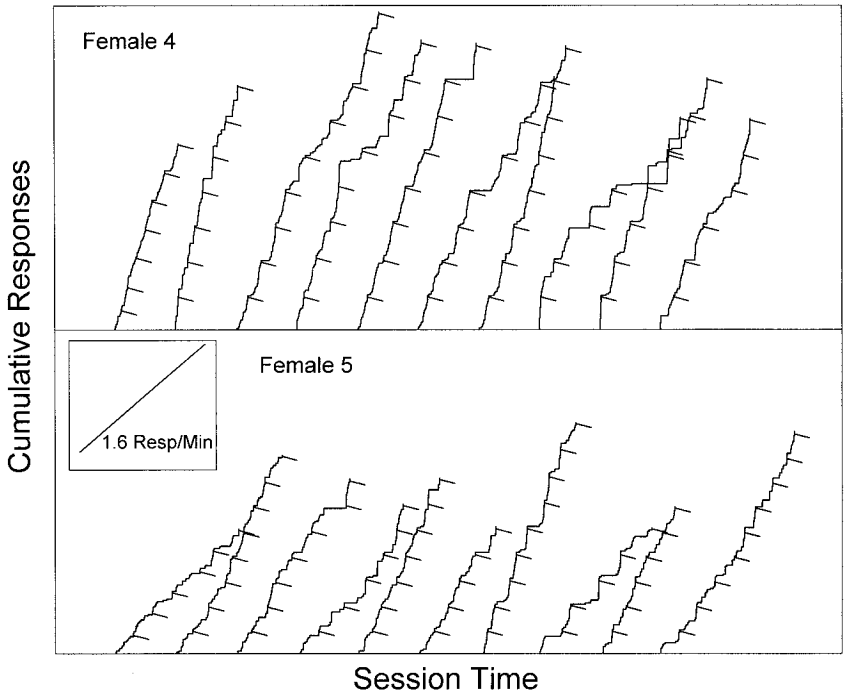

Fig. 3. Cumulative records for Subjects 4 and 5 on FR schedules. Ten sessions at FR 25 are shown for Subject 4 and 10 sessions are shown for Subject 5, of which the last eight were at FR 18 and the initial 2 days were at FR 14 and FR 15. The downward pip mark indicates the time of the onset of the tone. The cumulative record did not advance during the reinforcer, and thus the slope of the record indicates response rate only during time in the female's compartment.

nose-poke responding assured that at least 10 responses per session were followed by scheduled consequences.

With the introduction of sexual reinforcement, however, response rates increased substantially for all subjects. An increase in rate on the first introduction of sexual reinforcement was seen for all subjects, and, over 22 sessions, response rates at least tripled for all subjects.

Figure 3 shows cumulative records from 2 subjects. Response rates were quite slow in comparison to what would be expected for rats trained on comparable schedules of food reinforcement, even with very low levels of deprivation (Ferster & Skinner, 1957). With regard to the grain of these records, it is clearly apparent that the pattern of responding was highly irregular, not resembling the usual postreinforcement pause-run sequence expected with food-trained subjects (Ferster & Skinner). Rather, it appears that breaks may occur at any point during the trial.

It may be the case, however, that one aspect of characteristic performance on ratio schedules may have emerged. It appears from the cumulative records that responding occurred in relatively rapid runs (Ferster & Skinner, 1957), which may indicate that the ratio schedule contingency had been at least partially effective.

Figure 4 presents an interresponse-time (IRT) analysis of the same data sets that are presented in Figure 3. Response probability corrected for opportunities is shown as a function of time between successive responses or between the beginning of a trial and the first response. The IRT axis is divided into 2-s bins. It is evident that short IRTs occurred in greater abundance than would have been expected from random responding.

With sexual reinforcement, the duration of sessions was determined by the number of intromissions that occurred prior to ejaculation by the male. The average number of reinforcers over all subjects was 5.4; individual av-

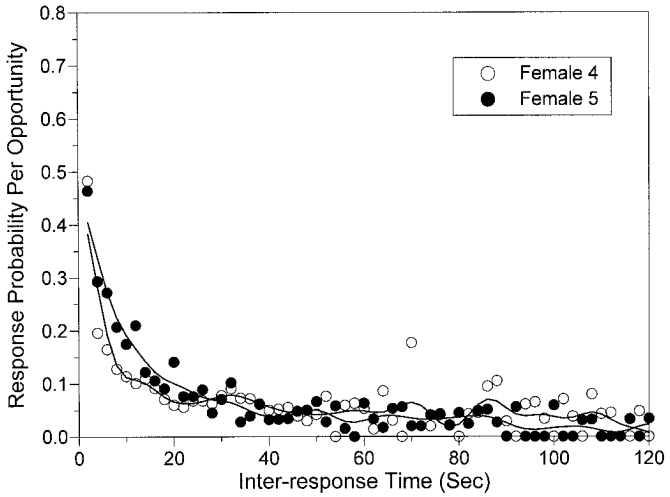

Fig. 4. The data shown in Figure 3 are presented in an IRT analysis. The conditional probabilities of a response at various IRTs divided into 2-s bins are shown for Subjects 4 and 5. IRTs less than 100 ms are disregarded. The data for each animal are fitted by curves that are smoothed by averaging *y* values for adjacent *x* values into each *y* value.

erages were 4.90, 6.64, 4.62, 6.30, 5.90, and 4.26.

Hormone supplementation sustained responding over about a 6-month period, during which some 50 to 70 sessions were conducted with this group of females (not all of these data are reported here). Beginning with the 40th session, all females began to show sporadic unreceptiveness. Unreceptiveness was usually evident at the very beginning of a session and did not often emerge during a session.

Discussion

None of the tone or odor conditions seemed to function as reinforcing or punishing consequences of responding. All subjects responded spontaneously with sufficient frequency that any effects of consequences should have been noted. Although the tone was not expected to produce an effect, it was expected that perhaps odors derived from either the bedding of the male or directly from the preputial gland would be effective reinforcers, even for sexually naive females. Carr, Loeb, and Dissinger (1965), for instance, have shown that odors play an important role in the modulation of sexual behavior in rats. Although there may have been a slight indication of some effectiveness of the preputial gland scent, the magnitude of this effect paled in comparison to the effect of access to the male as a reinforcer. There can be little doubt that the odors reached the females, because both the automated switching of the air pump pressure and negative pressure created by the exhaust fan quickly filled the nosepoke cylinder following a breaking of the photocell beam that recorded a response.

Several points of comparison to the conventional results with food reinforcers are worthy of note. First, the overall rate of responding, even with well-trained subjects, was quite low. Informally, it appeared that the females had a lower overall activity level than is typical with hungry rats. Although this may represent a difference in the energizing effect of sexual motivation, other aspects of the procedural differences between food and sexual reinforcement may also be at play.

The difference between FR performance with sexual reinforcement and food reinforcement or even wheel-running reinforcement (Iversen, 1993) is quite striking. Despite 10 sessions of training on FR 25, for instance, Subject 4's responding remained generally slow and erratic. The failure to observe typical pause-run sequences may derive from an intrinsic property of sexual reinforcement or may reflect particular procedural differences. For instance, the ratio criteria were increased every few sessions until the final value was reached; this may have in effect rendered the FR schedule more variable than would be the

case if more training sessions had been provided. Moreover, the variable duration of the reinforcer may have interfered with the development of the pause-run sequence.

Figure 4 suggests a possible point of similarity to one aspect of food-reinforced FR performances; responding seemed to gather into runs or bursts. The distribution of IRTs suggests that responding occurred in relatively high-rate bursts of responding separated by variously prolonged IRTs. This would be expected on the basis of the contingency between response rate and reinforcement rate that is inherent in ratio schedules. In contrast, variable-interval (VI) schedules provide a relatively weak response-rate reinforcement-rate contingency. It is interesting that parallel analyses of VI performance for food reinforcement in rats suggest less prominent short-IRT modes (Anger, 1956; Kintch, 1965). It should be noted, however, that these experiments used a bar-press response rather than the nose-poke response used in the present study.

The session duration of an average of only 5.4 reinforcers per session is clearly a limiting factor for the study of sexual reinforcement. This low number obviously poses a problem for the use of sexually reinforced behavior in steady-state experiments, much less the analysis of simple contingency effects.

Another limiting factor is the span of time over which the hormone replacement procedure seems to be capable of maintaining receptiveness in the female. Although the persistence of receptiveness shown here is sufficient to allow useful experimentation, it would be helpful to extend and stabilize the period of receptiveness induced by hormone replacement.

EXPERIMENT 2

It appears from the above results that the behavioral preparation for the functional analysis of sexual reinforcement should be modified so that more data can be extracted from the time during which hormone replacement treatments are effective and stable. In the following experiment several modifications were made to accomplish this goal. The first and most direct was the replacement of hormone injections by implantation of a slow-release estrogen-filled silastic capsule. The second change was the replacement of the nose-poke response with a nose-press response, a response that should have a lower spontaneous rate of occurrence so that contingency effects will constitute a higher proportion of control over responding. Third, the rat strain was switched to Sprague-Dawley on the basis of informal indications from other laboratories that these females might be more receptive (Pfaff, personal communication, 1996). The third modification addresses the limitation imposed on session duration by male ejaculation after 12 intromissions at most. Coopersmith, Candurra, and Erskine (1996) have shown that females will allow successive intromissions by more than one male. Using this observation, we attempted to extend test sessions by modifying the test chamber to allow 2 male rats to serve alternately as the target rat. In our new test chamber, the experimenter used a gate to select which male was available to the female when the partition was lifted.

Method

Subjects. Five sexually naive and ovariectomized female Sprague-Dawley rats were purchased from Charles River Laboratories and were delivered at 225 g body weight. They were housed as the subjects were in Experiment 1. Hormone replacement was accomplished by subcutaneous implantation under pentobarbital-ketamine general anesthesia of 5-mm silastic tubes filled with estradiol benzoate powder. The rate of diffusion of the hormone into the blood stream maintains a systemic level comparable to that of estrus (Parsons, Krieger, McEwen, & Pfaff, 1979).

Four sexually experienced Sprague-Dawley male rats were purchased as retired breeders from Charles River Laboratories. These animals weighed approximately 350 g on delivery.

Apparatus. The test chamber used in this experiment is shown in Figure 5 and is different from that used in Experiment 1 in several respects. The male's compartment was widened so that 2 males awaited the female. A movable vane allowed the experimenter to determine which chamber the female entered when the partition was lifted. In addition, the manipulandum was a pigeon response key centered on the female's side of the partition wall, 2.5 cm from the floor. The

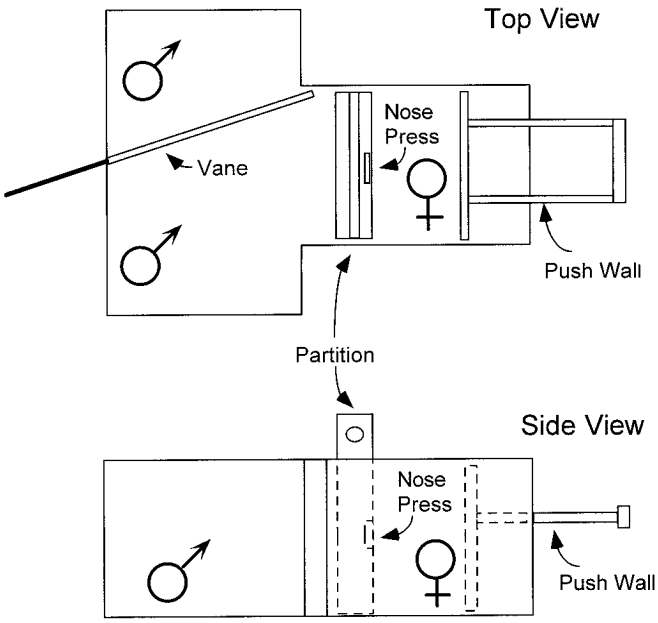

Fig. 5. This version of the test chamber is physically and operationally very similar to that shown in Figure 2 except that 2 male targets are available as reinforcers. The males are located in the two chambers on the left, separated by the movable vane. The experimenter selected which male would be the target on a given trial by manually positioning the vane.

response detector was a 1.5-cm plastic disk recessed 0.4 in the partition surface. The spontaneous level of nose presses was generally much lower than the nose-poke response. No odorants were presented in this experiment. The female's compartment was 20 cm by 20 cm by 20 cm and was somewhat smaller than that used in Experiment 1. Otherwise, the two test chambers were physically and operationally identical.

Procedure. Each session started with 2 randomly selected target males in the male's compartments. The first male to receive the female was selected at random by the computer. Thereafter, each male received the female on alternating bouts of three successive trials. To switch target males, the experimenter repositioned the vane separating the male's compartments. If a male failed to approach the female within 45 s, the trial was terminated and the vane was shifted to select the other male on the subsequent trial. If a male ejaculated, the vane was switched to the other male on the next trial and the original male was replaced. The session ended when the female failed to respond within 4 min of trial initiation.

Results

The nose-pressing response was established in 4 of the 5 female rats by reinforcing successive approximations (shaping). The average number of shaping sessions required for shaping here was 6.5, and the average number of reinforcers required was 53. For individual subjects the mean number of sessions required for shaping were 3, 5, 8, and 10 and the mean number of reinforcers required were 28, 25, 50, and 100. The 5th rat became unreceptive to the males after nine sessions of training, perhaps because of a faulty capsule implant. Testing was continued for 42 sessions over a 4-month period, with no indication of a decline or instability in female receptiveness.

Once responding was well established, the 2-male target procedure succeeded in increasing the average number of reinforcers per session from 5.8 in Experiment 1 to 15.1. For individual subjects the mean number of

reinforcers per session were 8.3, 26.0, 14.7, and 11.35. The maximum observed was 66 intromissions, which vastly exceeds the number of intromissions in the naturally occurring ejaculatory sequence (normally a maximum of 12). That the males were capable of this number of intromissions without ejaculation was unexpected and is presumably a result of the pattern of alternating access to the female.

Discussion

Shaping the nose-press response was somewhat more time consuming than is usually the case with food reinforcers. In a similar experiment not reported here, nose pressing was shaped in female rats for food reinforcement instead of sexual reinforcement. Using the sexual reinforcement test chamber, they were fed when they got to the otherwise empty male's compartment and were returned to the female's compartment by the same method used in the present experiments. Three rats learned the response in the first session, and all 7 had learned by the third. The maximum number of required reinforcers was 30. Although it may be of interest to assess the origins of this apparent difference in the ease of shaping, it is more important to note from these observations that shaping with sexual reinforcers is not insurmountably difficult and can be done successfully with a response that has a low operant level.

These data do not allow a conclusion to be drawn about the effects of the implanted capsule estrogen delivery system on the stability and persistence of female receptiveness. The termination of the experiment after 42 sessions precluded a clear picture of the decline of receptivity. In other respects, however, the method was clearly superior to the regular injections used in Experiment 1. Injections invariably produced squealing and often resulted in the accumulation of a bolus of the oil vehicle under the injection site, sometimes lasting several weeks. The capsules, on the other hand, showed no sign of irritating the females, and there were no complications from the surgery.

The use of 2 male targets is probably the most important modification introduced in Experiment 2. Doubling the number of targets nearly tripled the number of reinforcers per session. On most sessions, over 20 reinforcers were earned. Because the sessions in Experiment 1 were invariably ended by ejaculation rather than by a failure of the female to respond, the length of the session was limited by the male, not the female. In the present procedure, sessions were ended only when the female stopped responding. This observation is of special interest because it so greatly exceeds what is expected from both males and females on the basis the normal mating pattern. Clearly the system that accomplishes normal mating is quite capable of different behavior patterns when the situation is not normal. Equally clearly, an understanding of sexual motivation based exclusively upon naturalistic observations of normal patterns is likely to be in error.

GENERAL DISCUSSION

Sexual reinforcement has been demonstrated to be a manageable reinforcer for the kind of functional analysis that has illuminated the nature of other reinforcers such as food and water. On the other hand, our initial observations indicate that there may be important differences between this reinforcer and, for instance, food as a reinforcer. This is not to say that the differences are intrinsic to the reinforcer types. They could as well be related to a host of more superficial properties of the sexual reinforcement versus the food reinforcement procedures. Numerous procedural differences are necessary to allow sexual reinforcement. Most conspicuously, the reinforcing event is different from the consumption of a food pellet. The sexual encounter takes almost a minute to unfold, on average, and may have inherent aversive properties that carry over in the postreinforcement period (Erskine, 1989). Further, there is considerable variability in the presentation of sexual reinforcement because it involves another rat and is, therefore, inevitably a complex event. Finally, it is not altogether clear that the reinforcer used here is actually sexual in nature. We have not controlled for the possibility that the female might have responded for simple social access to the male.

It is also the case that the sexual reinforcement procedure involves quantitative properties that are quite different from those of the typical food reinforcement procedure. For instance, there is a substantial and vari-

able delay between the correct response and the intromission, which, although it was signaled by a tone as a conditioned reinforcer, may have substantially weakened the effectiveness of the presumptive reinforcer. In addition, the delay between response opportunities as well as the relocation and handling of the animal between response opportunities might have important effects.

In all, it is not possible from these data to draw any conclusions about fundamental differences between food and sexual reinforcement. The procedural and quantitative differences may indeed fully explain the patterns of behavior observed here. In support of this conclusion, running-wheel activity, another noningestive, probably nonhomeostatic reinforcer, can function much like food reinforcement in its effects on reinforced responding (Iversen, 1993).

Although we are without a clear indication of the underlying mechanisms that support the observations reported here, it is nevertheless important to note that our procedures bring to light a variety of interesting differences that must be considered in the design of future experiments and that pose questions for experimental analysis. For instance, the sexual reinforcer seems to be rather less easily put to the task of differentiating novel behavior (shaping). Although this does not pose a formidable obstacle to experimentation, an adaptation of the usual techniques that might improve the efficiency of such experimentation would be welcome. One theoretically interesting interpretation of this result is that it might be related to the informal observation that females exhibited much less exploratory behavior during the shaping sessions than is usually the case with food-deprived subjects. This might be an intrinsic property of sexual motivation that would constrain the learning of new responses.

Sexual reinforcers, as used here, appear to be less effective than food reinforcers (as typically arranged) in strengthening and maintaining an operant response. Although a stable response was established with both of the operants presented here, the rate of occurrence, even on FR schedules, was lower than that commonly associated with food-reinforced responding. Moreover, the pattern of responding on FR schedules over extended training showed no signs of increasing strength or more coherent pause-run patterning. These rather large differences invite further experimentation to isolate their origins. We are hopeful that the sexual reinforcement procedure described here may be a useful preparation for that analysis.

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